Environmental innovation dynamics in the pulp and paper industry: A case study in the framework of the project 'Assessing innovation dynamics induced by environment policy'

Kuik, O.J.

2007

Environmental Innovation Dynamics in the Pulp and Paper industry

A case study in the framework of the project ‘Assessing innovation dynamics induced by environment policy’

Onno Kuik

E-07/04

November 30, 2006

This report was commissioned by: European Commission, DG Environment, Contract No. 07010401/2005/424497/FRA/G1

IVM

Institute for Environmental Studies
Vrije Universiteit
De Boelelaan 1087
1081 HV Amsterdam
The Netherlands

Tel. ++31-20-4449 555
Fax. ++31-20-4449 553
E-mail: info@ivm.falw.vu.nl

Contents

Abstract

This paper addresses the innovation dynamics induced by environmental policy in the pulp and paper industry. There has been a fair amount on technical change in the pulp and paper industry in the recent past and there are still plenty of options for improvement. Innovation and diffusion of new technologies have occurred with respect to end-of-pipe abatement, on processes and the product (paper) itself. The main drivers for innovation in the pulp and paper industry are competition and market demands, but environmental policies have also played a role. With respect to the types of policy instrument most conducive to innovation, the paper suggests that it is not primarily the type of instrument (economic, command-and-control, voluntary) that matters, but much more its design characteristics, such as intensity (how ambitious are its targets?), flexibility (does it allow temporary derogations from standards to allow for innovative experiments?), and dynamic properties (does it continuously and predictably tighten its standards in future?). The IPPC Directive has the potential to stimulate innovations in the pulp and paper industry, depending on how environmental authorities deal with its integration-approach in practice.

1. Introduction

Pulp and paper is a mature industry. Industrialised paper manufacturing in Europe started in the early 19th century (Berkhout, 2005). It is a capital and resource-intensive industry that contributes to many environmental problems, including global warming, human toxicity, eco-toxicity, photochemical oxidation, acidification, nutrification, and solid wastes (Blazejczak and Edler, 2000).

Paper is made of natural fibres, either from wood or from recycled materials. Figure 1 below presents a schematic representation of the production system. The harvested wood is first processed so that the fibres are separated from the unusable fraction of the wood, the lignin. Pulp making can be done mechanically of chemically. The pulp is then bleached and further processed, depending on the type and grade of paper that is to be produced. In the paper factory, the pulp is dried and pressed to produce paper sheets. Post-use, an increasing fraction of paper and paper products is recycled in Europe. Non-recycled paper is either landfilled or incinerated.

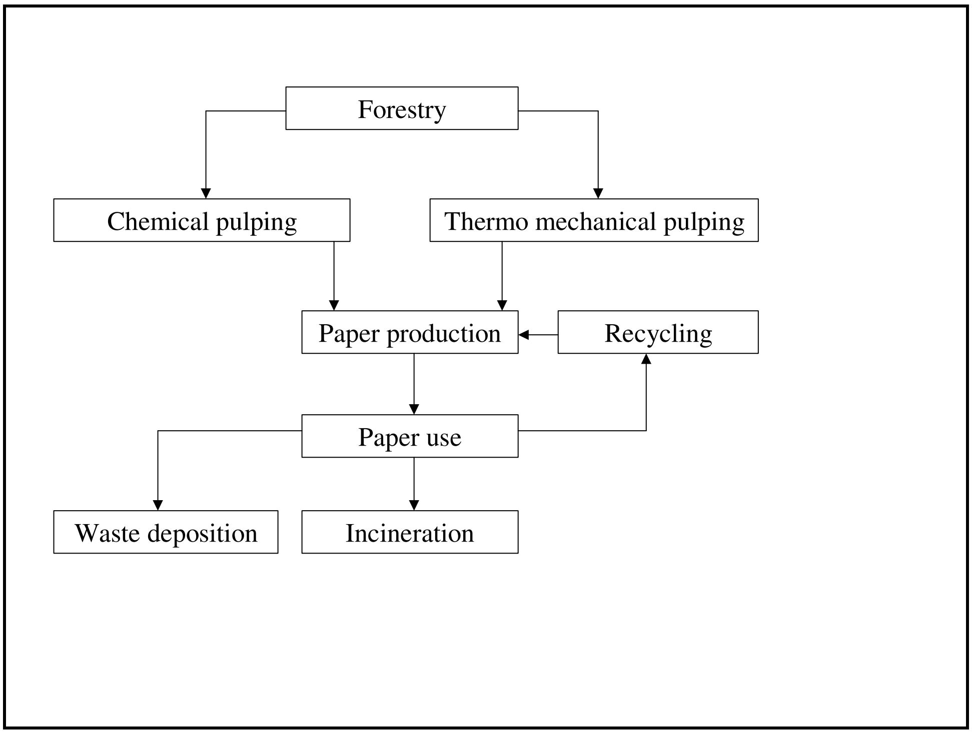

Figure 1.1 Paper production system (from: Berkhout, 2005).

Each node of the production system in Figure 1 has its own environmental problems and each node also has its own potential for innovation. The pulp and paper industry has undergone some major changes in environmental performance in the last two decades, which, according to some observers, is quite surprising for an industry that has often been taken as an example of a mature sector with a low rate of innovation (Reinstaller, 2005). The most spectacular changes in the recent decades have been a radical change in bleaching technology, that minimised the use of chlorine and greatly reduced or avoided altogether the emissions of dioxins (Reinstaller, 2005), and the increase in the use of recycled paper as an input in the paper production process. Although less spectacular and more gradually, the pulp and paper industry in Europe has also improved its performance in other environmental dimensions (Berkhout, 2005).

This paper examines the main drivers of this environmental innovation and specifically addresses the part of environmental policy in this process. Based on a comparative analysis of the development of the pulp and paper sector in different countries, the paper also examines whether different policy approaches have mattered for the speed and depth of environmental innovation. Additional information on the relationship between innovation and environmental regulation has been obtained by interviews with industry experts in different countries (see Appendix II).

This paper's focus is the pulp and paper industry, narrowly defined. The paper does not deal with broader sustainability issues regarding paper production and use, and also does not consider for 'disruptive' forms of innovation, such as innovations in the nanotechnology and biotechnology sectors which are looking for alternatives to wood based paper.

Prior to addressing the main question of this study, the next section of this paper examines technical and environmental change in the pulp and paper sector in more detail.

2. Technical and Environmental Innovation

In the pulp and paper industry, as in other industries, it is useful to make a distinction between innovations in abatement technology, process changes and product changes. The interrelationships between these different types of innovations are graphically represented in the Innovation Triangle (Figure 2). The different types of innovations in the Innovation Triangle are in their turn all dependent upon the underlying socio-technical infrastructure in which the pulp and paper firms operate. In the last two decades, the pulp and paper industry has had innovations in all corners of the Innovation Triangle.

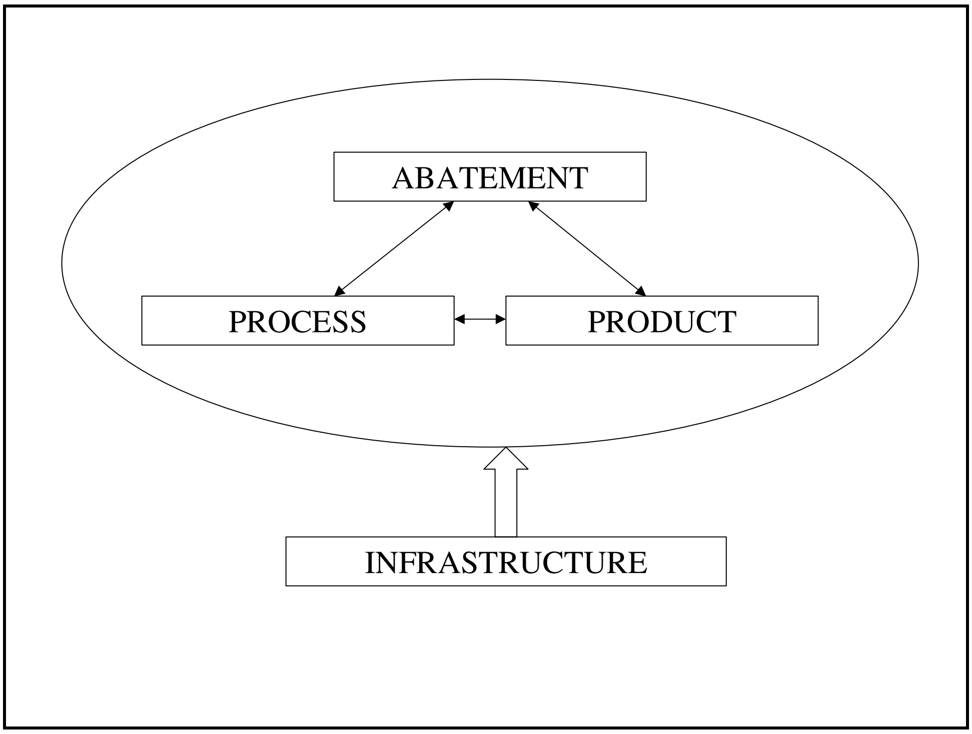

Figure 2.1 The Innovation Triangle (from: Berkhout, 2005).

Berkhout (2005) argues that the source of pressures on each corner of the Innovation Triangle differs. Pressure on abatement tends to come from the environmental authorities; pressures on process changes come from competitors and customers; whereas pressures on products come from consumers and pressure groups. Moreover, changes in one corner of the Innovation Triangle affect changes in both other corners through dynamic interlinkages (depicted by the arrows in Fig. 2). As we will discuss below for example, consumer demand for the *product* chlorine-free paper, indirectly affected the *process* of bleaching, and henceforth the need and technology of *abatement* of certain toxic pollutants.

Abatement of pollutant emissions has mainly been triggered by environmental policies that have required waste water treatment. Process changes have predominantly been triggered by the competitive need to economise on resources (e.g., higher energy efficiency in pulping, and a more productive use of heat and the unusable wood fraction of the pulp process (black liquor)). An important barrier to quick process changes is the industry's slow capital-turnover rate. A survey in 1997/8 revealed that the median age of paper machines in Europe was 23 years (Berkhout, 2005). Recent research undertaken in the USA suggests a potential negative correlation between environmental innovation and sunk costs. The research suggests that no matter what the regulator does, because there will be much lobbying and negotiations undertaken as a part of the permitting process, regulators tend to favour existing actors over potential new entrants. The indirect impact this can have on the innovation process can be potentially huge since the vehicle on which innovation and new ideas enter the sector is often through new entrants to the market.

Product changes, such as the transition toward chlorine-free paper have been triggered by consumer demand and actions by influential environmental groups such as Greenpeace (Reinstaller, 2005). Table 1 below summarises some of the main environmental changes in the pulp and paper industry in the recent past and their main drivers.

Table 2.1. Technology changes underlying environmental performance dynamics in pulp and paper production: 1980-95.

Indicator	Key technology drivers of environmental performance change
CO2	Background energy mix
Timber use	Product change (higher filler and recycled fibre content in paper), process change (fibre stock recirculation).
NOx	Energy efficiency (transport), process change (energy efficiency in pulping), background energy mix change
SO2	Sulphur dioxide abatement (pulping)
BOD (Biological Ogygen Demand)	Abatement (waste water treatment), process change (heat recovery from organic puling wastes in mechanical pulp), product reformulation (higher recycled fibre use).
COD (Chemical Ogygen Demand)	Waste water treatment
AOX (dioxins)	Process change (elemental or total chlorine-free bleaching)

Source: Berkhout, 2005

Most, if not all, analysts of the environmental performance of the pulp and paper industry argue that the change in environmental performance in this industry is the result of several drivers of which some were directly targeted at environmental improvements, while others were not (a.o., Berkhout, 2005; Blazejczak and Edler, 2000; Hildén *et al.* 2002; Kivimaa and Mickwitz, 2004).

Calleja *et al.* (2004) identified a large number of innovations in technology, process and management in the pulp and paper industry that can contribute to more environmentally benign pulping and bleaching methods, increased use of recovered paper and fillers and in-house water recycling. They made a distinction between available and emerging technologies. Available technologies are already implemented by a number of firms, but are not yet common practice within the entire sector. Emerging technologies are those technologies in the development phase or that have been implemented only in a very few firms. Table 2 below lists the available and emerging technologies in stock preparation (pulping), the use of recycled paper and paper production proper. The main purpose of Table 2 is to show that there is still much to be gained in the environmental performance of the average pulp and paper firm in Europe, both through increased diffusion of available technologies and through the adoption and further development of emerging technologies.

Table 2 Available and emerging environmental technologies in the pulp and paper industry

	Available	Emerging
Pulping	Modified cooking	Impregnate wood chips with black liquor
	Oxygen delignification	Use of polysulphide and anthraquinone
	Biological/secondary treatment of wastewater	Even concentration of hydroxide in digester
	Collection and incineration of maloderous gases	Condensing steam to generate more electricity
		Increased system closure combined with kidneys
		Pressurised black liquor gasification
		SNCR on the recovery boiler
		Recycling all the electrostatic precipitator dust
		ASAQ/ASAM
		Removal of chelating agents
	Mechanical pulping under elevated pressure	New evaporation techniques as “kidney” for internal cleaning of process water
	Heat recovery in thermo-mechanical pulping	New energy-efficient thermo-mechanical pulping processes
	Improvements of refiners	
Recovered paper	Treating internal water circuits for non de-inked grades	Membrane filtration and ozonation
	Co-generation of heat and power	Kidney treatment for further cleaning and re-use of water
	Low NOx boilers	Continuous batch fibre recovery system
	Anaerobic and aerobic biological treatment	Enzymatic de-inking
	Partly recycling of treated water	Tertiary effluent treatment
		Membrane bioreactor
Paper production	Control of closed water systems	Impulse technology for dewatering
	Low NOx auxiliary boilers	Condebelt processes
	Combined heat and power generation	Internal heatpumps
	Secondary or biological treatment of waste water	Total site integration tools

Source: Calleja *et al.*, 200

3. Drivers and Policy Instruments

The various drivers that have affected environmental performance in the pulp and paper industry have affected firms in different countries in different ways. Reinstaller (2005) examined the differences in responses to the market demand for chlorine-free paper in Sweden and the United States. A remarkable difference between these countries is that while the most environmentally advanced, but more expensive chlorine-free technology (total chlorine free bleaching: TCF) penetrated the Swedish pulp and paper industry to a significant extent,[1] it did not in the United States and Canada where the industry did not move beyond the relatively less environmentally advanced technology of elemental chlorine free bleaching (ECF). Reinstaller (2005) attributes these differences in the diffusion rates of the TCF technology to differences in the public perception of the health risks of dioxins[2] and the strong role of Greenpeace as a "policy entrepreneur" in Europe. Environmental policy may have played a role in the diffusion of the TCF technology in Sweden, but only indirectly, as firms might have anticipated stricter standards in the future (based on the precautionary principle) (Hildén et al, 2002).

One of the leading Swedish paper producers, Södra, used its choice for the TCF technology in their marketing strategy for zero chlorine pulps and paper (Reinstaller, 2005). Initially, in the early 1990s, Södra could sell TCF paper at a premium to make up for higher production costs. By, 2002, however, TCF paper had become "mainstream" and could be produced at the same cost (and with the same quality) as ordinary paper (Rodden, 2002). A production manager of Södra remarked that growth in TCF paper may be limited due to the time it takes to learn to produce and bleach it properly. He adds: "It took us a long time" (Rodden, 2002:21).

Blazejczak and Edler (2000) examined differences in trends in innovations in specific energy consumption in the pulp and paper industry and waste paper recycling, and confronted these trends with different regulatory approaches in Germany, Japan, Sweden and the United States.[3] Based on a somewhat flawed analysis,[4] Blazejczak and Edler

---

1 From 1990 to 1999, the share of TFC in Sweden increased from zero to almost thirty percent (Reinstaller, 2005: Fig.3).

2 Health risks were especially feared in Germany, the biggest export market of Swedish paper. A main event in the German sensitivity to the risks of dioxin was the Seveso incident (1976) in Italy, where dioxins were released to the environment after an accident in a chemical plant (Reinstaller, 2005).

3 Unfortunately, no data on specific energy consumption were available for the Unites States, so the quantitative comparison of the paper is somewhat handicaped. Specific energy consumption (tons of oil-equivalent per ton of production) in the pulp and paper industry is lowest in Japan, somewhat higher in Germany and highest in Sweden. Over the period 1970-1992, the trend is stable in Japan, decreasing in Germany, and first increasing and then decreasing in Sweden. Waste paper recycling is highest in Germany and Japan, intermediate in the United States and lowest in Sweden.

4 In explaining the different trends described in the previous footnote , Blazejcak and Edler (2000) do not differentiate between external factors such as energy prices and resource abundance (virgin wood in Sweden) and policy approaches, so that their overall conclusions on innovation-friendly policy approaches are not firmly rooted in their empirical analysis.

(2000) conclude that Swedish policy is most innovation-friendly because it is characterised by a search for consensus in combination with ambitious long-term goals. Japan's policy with respect to the pulp and paper industry is considered to be less innovation-friendly, mainly because Japan does not consider its pulp and paper industry as a 'strategic' sector in industrial policy.[5] Finally, environmental policy in the United States is considered to be least innovation-friendly as it relies too much on technology (BAT) standards and offers, because of its legalistic nature, little flexibility to individual firms.

In a detailed policy impact study concerning the Finnish pulp and paper industry, Hildén *et al.* (2002), draw some interesting conclusions on the links between policy instruments and (environmental) innovation and diffusion.

Firstly, it is noticed that Finnish regulatory practice in the pulp and paper industry concerning air and water pollution has not been innovation-forcing as it is based on the BAT concept and limit emission values could therefore be met by existing abatement technologies. This does not preclude, however, that the regulatory system has enhanced competition among suppliers of end-of-pipe abatement technologies and has thus provided incentives for innovation. The fact that waste water permits have tightened over time, may also have provided some incentives for innovations for operators, especially for those who wanted to expand their operations.

Secondly, a strong pint of the Finnish regulatory process is its transparency and the inclusion of the public in decision-making in water and air pollution issues. Transparency and participation are relatively effective weapons against 'regulatory capture' and safeguard a consistent 'policy line' which is appreciated by the industry as well as the administration.

Thirdly, the flexibility of the Finnish permitting practice at the plant level made it possible for operators to obtain temporary reliefs during demonstration periods or plot phases of new end-of-pipe technology. Hildén *et al.* (2002) favourably compare the informal Finnish permitting practice in this respect with the formal and bureaucratic "innovation waivers" in the United States (cf. Derzko, 1996).

Fourthly, interviews with pulp and paper operators suggested that some permit requirements, for example regarding recycling of water and materials, may have helped operators to identify potential cost savings and may have promoted process innovations. Hildén *et al.* (2002) are careful to note, however, that it remains an open question whether the operators would not have identified these potential cost savings without the regulation being in place.

Fifthly, the regulatory framework in Finland has promoted the diffusion of end-of-pipe abatement technologies in the areas of water and air pollution. Hildén *et al.* (2002) note, however, that the diffusion of waste water treatment plants in Finland was comparable to diffusion processes in other countries that used other policy instruments or other implementation approaches. For example the diffusion pattern was quite similar to that in the Netherlands which' policy approach relied on effluent charges.

---

[5] We do not know on what criteria Japan selects its strategic industries, but we assume that the potential for (export) growth is one of the criteria.

Sixthly, Hildén *et al.* (2002) notice that Research and Development (R&D) requirements in permits have not had any discernible impact on innovation and diffusion. Likewise, electricity taxation in Finland has also not played any discernible role in promoting innovations in and diffusion of energy-efficient technologies. Hildén *et al.* (2002) suggest that the reasons for this lack of impact may lie in (1) the "vagueness" of the R&D requirements, and (2) that the electricity taxes have been too low and too prone to exemptions and counteracting subsidies (see also Similä, 2002). Finally, Environmental Management Systems in firms were found to make a positive contribution to innovation and diffusion, but only in an incremental way, hence there was no evidence that Environmental Management Systems in firms contributed to major environmental improvements.

Similä (2002) addresses the question whether environmental permits under the new IPPC (Integrated Pollution Prevention and Control) Directive will be more supportive of (process) innovation than the old system of media-specific emission limit values and permits in Finland.[6] According to the rationale of the IPPC Directive this should be the case.[7] It is assumed that the integrated approach of the IPPC will shift the focus from end-of-pipe technology to process technology and, hence, support (process) innovation Similä (2002) argues that the potential flexibility of the IPPC is mainly in the pre-decision phase of the permit making process. The IPPC approach would increase the asymmetry of information between operators and the authorities. Operators could use this advantage to decrease control costs by adopting innovative (process) solutions. Authorities, on the other hand, might fear to loose control over the permitting practice and stick to the conventional environmental media approach. On the basis of ongoing research, Similä (2002) posits that Finnish permitting authorities do seem to stick to their old ways, despite "vague" references to integration. This could, of course, change in time when authorities get more experience with the integrated way of permit setting.

Kivimaa and Mickwitz (2004) stress the importance of co-operation between environmental authorities and the organisations that provide R&D support to technologies that may potentially affect the environmental performance of firms. If such co-ordination is in place there is less risk of wasted R&D resources for technologies that will be impeded or blocked by environmental policy measures. Conversely, it is important that environmental authorities are aware of technological options and developments so that policies can be redirected accordingly (Kivimaa and Mickwitz, 2004)

Chappin (2005) examines the impact of environmental regulations on innovation activity in the areas of waste water, solid waste and energy-efficiency in the paper and board industry in the Netherlands over the period 1980-2003. She measures innovation activity in a particular year by the number of new research projects that were initiated in that year by the Dutch Paper and Board Association and its associated research centres. She examines whether there are different innovation responses to different policy instruments. She distinguishes between top-down instruments (command-and-control), economic instruments (negative economic instruments such as taxes and charges on the one hand, and

---

6 The provisions of the IPPC Directive are implemented in Finnish law through the Environmental Protection Act of 2000.

7 Explanatory memorandum of the IPPC Directive.

positive economic instruments such as subsidies on the other hand), and interactive instruments. One of the interactive instruments used in the Netherlands is known as Target Group Policy, where collective environmental targets for an entire industry are set through an interactive process between government and the relevant industry association. Once these collective targets are set, the industry association co-ordinates the abatement efforts of its members.

The study finds no direct association between the implementation of policy measures and the number of new research projects in the areas studied, with the exception of research projects on energy-efficiency that increased in number in the period 1994-5 after the signing of the first Long Term Agreement on energy-efficiency between government and the industry in 1993 (an interactive policy instrument). One of the reasons for the lack of association that is suggested by Chappin (2005) is that because of the steady accumulation of new policy measures applicable to the sector, it is difficult to directly link research and specific policy measures.

In a follow-up study, Chappin and others (2005), examine the relationship between the accumulation of policy measures – labelled as “policy pressure” – and collective research effort in the Dutch paper and board industry. The study finds no direct association between policy pressure and collective research effort, again with the exception of research on energy efficiency. Research on energy efficiency has been of interest for the industry during the entire period of examination (1980-2003), but increased somewhat in years after increases in policy pressure.

4. Interpretation and analysis

Despite being a mature industry with a slow capital-turnover rate, the pulp and paper industry has in recent decades been innovative with respect to abatement technologies, process and product changes. Many of the changes were incremental and end-of-pipe, but together they significantly changed the environmental performance of the industry in Europe. There are still various available technologies that could be further diffused across European pulp and paper mills, and there are many emerging technologies that could be further developed, tested and implemented.

Technological innovation in the pulp and paper industry is mainly driven by competition, cost considerations and market demand, but environmental policies also play a role. The typical environmental policy instrument in the pulp and paper industry is the firm-specific permit with limit effluent or emission values that are derived from characteristics of best available technologies (BAT). But also other instruments have been applied, such as water charges in the Netherlands and the electricity tax in Finland.

The evidence on the relationship between environmental policy instruments and innovation suggests that these instruments have not forced innovation, but they have not stifled innovation either.[8] The evidence reviewed in this paper suggests that, in practice, the type of policy instrument (economic, command-and-control) that is applied matters less, but that it is other characteristics of the instruments, such as intensity (how ambitious are its targets?), flexibility (does it allow temporary derogations from standards to allow for innovative experiments?), and dynamic properties (does it continuously and predictably tighten its standards in future?) that matter more. Detailed research in the Netherlands did not find a direct association between environmental regulation and collective research efforts in the areas of waste water and solid waste, but found a weak association in the area of energy efficiency.

Innovation in energy-efficiency are partly driven by environmental considerations and partly by considerations of costs and competitiveness. All experts notice an increasing concern in the industry for hard, financial targets, no doubt partly as a result of the increasing globalisation of the industry. Required pay-back periods for energy saving investments (e.g., combined heat and power) have, for example, decreased from five years in the early years of this technology to two to three years now in the Netherlands. In planning investments in the pulp and paper industry, including investments in innovation, the question is no longer only in what to invest, but increasingly also where to invest.

One of the industry experts remarked that, as a consequence of globalisation, future radical innovations can only be expected in areas where environmental improvements and

[8] Although there are examples of innovations in one area of environmental management that have been blocked by environmental policies in other areas. Chappin (2005) mentions the example of the so-called Rofire-installation that processes solid wastes into fuel pellets. The combustion of these pellets may contribute to energy savings but is not allowed in the Netherlands under current (air quality) legislation.

competitiveness go hand in hand.[9] Energy efficiency may be one such area. It is significant in this respect that the Dutch Paper and Board Industry Association has just recently presented its strategic energy and innovation agenda with the aim of halving the sector's energy use by the year 2020.[10] In this agenda, five innovation programs are identified:

1. Increased attention for energy-efficiency as an integral part of management in every paper plant;
2. A better utilisation of waste flows for energy generation with the ultimate aim of making paper production independent of fossil-fuel inputs;
3. Increasing material- and energy-efficiency by innovations in and better coordination of the supply chain of paper in relation to major users of paper, especially the packaging and printing sectors;
4. Development of multi-purpose bio-refineries where wood and paper waste and waste from other sectors (such as agriculture) can be transformed into useful products such as bio-chemicals, bio-ethanol, and other innovative bio products;
5. The reduction of the use of water in pulping, so that less energy is needed for drying. In the future, technical breakthroughs are contemplated that would completely avoid the use of water by substituting it by bio-ethanol or, perhaps, supercritical CO2.

It is too early to tell if this initiative will be successful, but it is pro-active and based on the expectation of commercial-attractive innovation in process and product, rather than re-active and based on passively following government regulation.

There is evidence that economic and command-and-control (permit) instruments had a about the same impacts on the dynamic diffusion of water treatment plants in different countries. On the other hand, there is evidence that low electricity taxes in Finland did not produce any innovation in the Finnish pulp and paper sector, while the gradual tightening of permit requirements in Finland may have contributed to innovation. The provisions of the IPPC Directive promise an even greater flexibility and options for (process) innovation than most old permit setting procedures, but it remains to be seen how environmental authorities deal with the integration-approach of the IPPC Directive in practice.

It is a common belief among innovation researchers that a clear, consistent and credible long-term vision on the sector's environmental performance, preferably shared by authorities and the firm operators, promotes innovation and diffusion of environmentally benign technologies. Consistency and credibility are supported by transparency and public participation, as was reported in the previous chapter. Economic and political uncertainty is detrimental to environmental innovation. One of the industry experts that were interviewed for this study argued that the introduction of combined heat-power technol-

---

[9] For an expert view on the relation between globalisation and environmental innovation, see Appendix I.

[10] See www.vnp-online.nl. Presently, the Association and individual companies are drawing-up individual innovation plans on the basis of this agenda.

ogy in the Dutch paper industry has been retarded by increasing uncertainty in the Dutch power market since the second half of the 1990s.

Although environmental policy has not forced innovation in a major way, it has also not stifled it. A comparison of US and European regulatory practice, suggested that the informal flexibility of regulators in some European countries at the plant level, may be much more conducive to innovation than the formal, bureaucratic US approach of "innovation waivers".

The literature suggests the importance of co-operation between environmental authorities and the organisations that provide R&D support. In general, extended knowledge networks are supportive of innovation and diffusion of new and environmentally benign technologies.

5. Summary and Conclusions

Pulp and paper is a mature industry. Industrialised paper manufacturing in Europe started in the early 19th century. It is a capital and resource-intensive industry that contributes to many environmental problems, including global warming, human toxicity, eco-toxicity, photochemical oxidation, acidification, nutrification, and solid wastes. Despite being a mature industry, the pulp and paper industry has undergone some major changes in environmental performance in the last two decades. The most spectacular changes in the recent decades have been a radical change in bleaching technology, that minimised the use of chlorine and greatly reduced or avoided altogether the emissions of dioxins, and the increase in the use of recycled paper as an input in the paper production process. Although less spectacular and more gradually, the pulp and paper industry in Europe has also improved its performance in other environmental dimensions, including improvements in energy-efficiency.

The literature reviewed in this study strongly suggests that the main drivers of environmental innovations in the pulp and paper industry in the recent past have been competition for new products, cost considerations and market demand. It has been suggested by industry experts that at present the impact of global competition on the pattern of innovation may be even larger than it was just a decade ago.

The evidence on the relationship between environmental policy instruments and innovation suggests that these instruments have not forced radical innovations. The evidence reviewed in this paper suggests that, in practice, the type of policy instrument (economic, command-and-control) that is applied matters less, but that it is other characteristics of the instruments (intensity, flexibility, dynamic orientation) that matter more. Detailed research in the Netherlands did not find an association between environmental regulation and innovation in the areas of waste water and solid waste, but found a weak association in the area of energy efficiency.

It is a common belief among innovation researchers and industry experts alike, that a clear, consistent and credible long-term vision on the sector's environmental performance, preferably shared by authorities and the firm operators, best promotes innovation and diffusion of environmentally-benign technologies. Some empirical evidence that was discussed above (the comparison between innovativeness of the paper and pulp industry in Sweden, Japan and the USA) supports this belief. But this is certainly an area where more research would be necessary.

The literature also suggests the importance of co-operation between environmental authorities and the organisations that provide R&D support. In general, extended knowledge networks are supportive of innovation and diffusion of new and environmentally benign technologies.

6. References

Berkhout, F.(2005). Technological Regimes, Environmental Performance and Innovation Systems: Tracing the Links. In: Weber, M. & Hemmelskamp, J. (Eds.) *Towards Environmental Innovation Systems*. p. 57-80, Springer, Berlin/Heidelberg/New York.

Blazejczak, J. & Edler, D. (2000). Elements of Innovation-friendly Policy Regimes – An International Comparative Study for the Paper Industry. In Hemmelskamp, J., Rennings, K. & Leone, F. (Ed.) *Innovation-oriented Environmental Regulation. Theoretical Approaches and Empirical Analysis.* p. 175-192. ZEW Economic Studies 10. Physica Verlag, Heidelberg/New York.

Calleja, I., *et al.* (2004). *Promoting Environmental technologies: sectoral analyses, barriers and measures.* IPTS report EUR 21002 EN. Institute for Prospective Technological Studies, Seville.

Chappin, M.M.H. (2005). *Environmental Regulation & Environmental Innovation: The Case of Wastewater Treatment, Waste and Energy-Efficiency in the Dutch Paper and Board Industry.* Proceedings of the 11th Annual International Sustainable Development Research Conference, 6-8 June, 2005, Tampere, Finland.

Chappin, M. M. H., Meeus, M.T.H., Hekkert, M.P. & Vermeulen, W.J.V. (2005). Dynamic Perspective on the Relation between Environmental Policy and Eco-Efficiency: The Case of Wastewater Treatment, Waste and Energy-Efficiency in the Dutch Paper and Board Industry. Paper submitted to *International Journal of Environmental Technology and Management*.

Clayton, T., Spinardi, G. & Williams, R. (1999). *Policies for Cleaner Technology.* Earthscan.

Derzko, N. (1996). Using Intellectual Property Law and Regulatory Processes to Foster the Innovation and Diffusion of Environmental Technologies, *Harvard Environmental Law Review,* 20(1), 3-59.

Hildén, M. Lepola, J., Mickwitz, P., Mulders, A., Palosaari, M., Similä, J., Sjöblom, S. & Vedung, E. (2002). *Evaluation of environmental policy instruments – a case study of the Finnish pulp & paper and chemical industries*. Monographs of the Boreal Environment Research No. 21, p. 134.

Kivimaa P. & Mickwitz, P. (2004). Driving Forces for Environmentally Sounder Innovations: The Case of Finnish Pulp and Paper Industry. In Jacob, K., Binder, M. & Wieczorek, A. (Eds.) *Governance for Industrial Transformation. Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change.* p. 356-372. Environmental Policy Research Centre, Berlin.

Kivimaa, P. (2006). Is there a role for environmental policies in supporting innovation? Comparing experiences from products and production technologies. INNOVATION PRESSURE Conference, 15-17th March 2006, Tampere, Finland.

Reinstaller, A. (2005). Policy entrepreneurship in the co-evolution of institutions, preferences, and technology. Comparing the diffusion of totally chlorine free pulp bleaching technologies in the US and Sweden. *Research Policy* 34 (9), 1366-1384.

Rodden, G. (2002). TCF is Here to Stay at Södra. *Pulp and Paper International*, 44 (10), 21-24.

Similä, J. (2002), Pollution Regulation and its Effects on Technological Innovations. *Journal of Environmental Law* 14 (2), 143-160.

7. Appendix I

Vision of the Confederation of European Paper Industries (CEPI) on the relationship between globalisation and environmental innovation.

A global vision requires global partnerships with global industries on global markets.

The human use of natural resources is part of a true global market, on which globalisation takes place at an incredible speed. The economic restructuring of the markets in which natural resources are raw materials takes place today. Emerging markets are more and more determining the developments. China, India, South America and Asia will play an increasing role in raw material supply and demand in the near future. Already European multinationals have become truly global and vice versa, more and more foreign companies operate on the European Market. This process might prove to be faster than environmental policy making at EU level, potentially making these policies obsolete before they start. Changing environmental performance on a global scale means that new policies should include this awareness. Existing policies should be assessed and redefined on their effects in these global markets.

A global vision on the European Environmental policy in general and the policies on natural resources in particular, should include a thorough analysis of the most important natural resources involved, the global raw material markets they constitute, the stakeholders in these markets and the decision taking within these parties. Not only should Europe assess its environmental impact in the world, its environmental instruments should have the ambition of solving global discussions instead of only adding local costs. It's the investment decisions in industry that policies should focus on, because these change the behaviour of tomorrow, not only the costs of today. For true ambition, industry policy has to meet environmental policy and vice versa. By definition this can only be done by voluntary partnerships.

8. Appendix II

The following industry experts have been consulted:

Mr. Marco Mensink, Energy & Environment Director, CEPI - Confederation of European Paper Industries

Ms. Maryse Chappin, PhD student at Copernicus Institute, Utrecht University